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Final Report for AASERT Program N00014-97-1-0557, "Nondestructive Three-Dimensional Microtexture/Strain Quantification in Al-Li 2090."

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Results

The AASERT program was to fund one graduate student and one undergraduate student. The emphasis was on interpretation of microtexture's role in crack deflection in Al-Li 2090; this allowed the parent program to devote more effort to strain measurements. Research focused on material just ahead of the crack tip and on how the fatigue crack "plane" develops under the influence of microtexture; understanding of microtexture is also essential to interpretation of the strain/stress measurements conducted in the parent program. In order to study these aspects of crack propagation, a new method of micro-texture tomography, with spatial resolution approaching that of optical microscopy, was developed utilizing microbeam synchrotron diffraction.

Research employed synchrotron polychromatic microbeams to map microtexture in three-dimensions in Al-Li 2090. The results expanded on earlier observations and are communicated in the publications tabulated below. Also of considerable interest was the demonstration that the synchrotron microbeams could produce transmission Laue patterns in reasonable times through 2-3 mm thicknesses of Ti-6Al-4V; this means that the techniques developed in this program will have much greater use in materials of interest to ONR.

Six invited presentations were given, two MS theses were defended successfully and 13 papers appeared (two in Acta Materiala, one in Philosophical Transactions of the Royal Society (London) and one in an ASTM STP. One paper is in press, two others have been submitted and several additional papers will be submitted in the future.

Student's Supported and Project Participants' Accomplishments

The following US citizens' graduate work was supported by this program: J.D. Haase, R. Morano. Their theses are listed below. A third MS thesis student, C.R. Patterson II who was supported by the predecessor AASERT grant, finished his thesis during the course of this program. The following US citizens served as undergraduate research assistants on this program: Chekesha Bradford, Tony Watt, Jennifer Hayes and Kimberley Smith. Patterson and Bradford are Afro-American.

The students who were supported on this program achieved significant recognition. Ms. Bradford won a NSF Graduate Fellowship, which she declined, and a DOD Graduate Fellowship, which she accepted. Mr. Haase won the 1998 Georgia Tech Sigma Xi Outstanding MS Thesis Research Award. Finally the project director, Dr. S.R. Stock, was promoted to Professor from Associate Professor in 1999.

Books written or edited by the Project Director:

1. Elements of X-ray Diffraction, Third Edition, B.D. Cullity and S.R. Stock, (Prentice-Hall, 2000).
2. Applications of Synchrotron Radiation Techniques to Materials Science IV, Materials Research Society Symposium Proceedings Volume 524, 1998, Susan M. Mini, Stuart R. Stock, Dale L. Perry and Louis J. Terminello, Eds.
3. Applications of Synchrotron Radiation Techniques to Materials Science V, Materials Research Society Symposium Proceedings Volume 590, 2000, Stuart R. Stock, Susan M. Mini and Dale L. Perry, Eds.

Publications:

1. "Three-dimensional Microbeam Diffraction Tomography of Fatigue Crack Asperities in Al-Li 2090," J.D. Haase, D.P. Piotrowski, A. Guvenilir, J.R.Witt and S.R. Stock, Advances in X-ray Analysis Vol. **41** (1998) 327-335.
2. "X-ray Microbeam Mapping of Microtexture Related to Fatigue Crack Asperities in Al-Li 2090," J.D. Haase, A. Guvenilir, J.R.Witt and S.R. Stock, Acta Materialia **46** (1998) 4791-4799.
3. "X-ray Microbeam Quantification of Grain Subdivision Accompanying Large Deformations of Copper," A. Guvenilir, G.C. Butler, J.D. Haase, D.L. McDowell and S.R. Stock, Acta Materialia **46** (1998) 6599-6604. Acta Materialia **46** (1998) 6599-6604.
4. "Micro-, Meso- and Macro-texture and Fatigue Crack Roughness in Al-Li 2090 T8E41," J.D. Haase, A. Guvenilir, J.R. Witt and S. R. Stock, MRS Symp Proc **524** (1998) 37-42.
5. "X-ray Microbeam Quantification of Grain Subdivision Accompanying Large Deformations of Copper," G.C. Butler, A. Guvenilir, D.L. McDowell and S.R. Stock, MRS Symp Proc **524** (1998) 43-48.
6. "Microtexture, Asperities and Crack Deflection in Al-Li 2090 T8E41," Jake D. Haase, Abbas Guvenilir, Jason R. Witt, Morten A. Langøy and Stuart R. Stock, in Mixed Mode Crack Behavior ASTM STP **1359** (1999) 160-173.
7. "New Direct Observations of Crack Closure Processes in Al-Li 2090 T8E41," A. Guvenilir, T.M. Breunig, J.H. Kinney and S.R. Stock, Philosophical Transactions of the Royal Society (London) **357** (1999) 2755-2775.
8. "Mesotexture, Deflection and Closure of Fatigue Cracks in Al-Li 2090 T8E41," S.R.Stock, in Advanced Materials for the 21st Century: The Julia R. Weertman Symposium, (TMS-AIME, 1999) 251-258.
9. "Polychromatic microbeam diffraction, mesotexture and crack deflection in Al-Li 2090 T8E41," J.D. Haase, R.Morano T.Watt and S.R. Stock, in Proceedings of the

Twelfth International Conference on Textures of Metals, Vol. 1, J.A. Szpunar, Ed., (National Research Council of Canada, 1999) pp.123-128.

10. "Macrotexture-related fatigue crack closure in Al-Li 2090 studied by x-ray microtomography," R. Morano, S.R. Stock, G.R. Davis and J.C. Elliott, in Proceedings of the Twelfth International Conference on Textures of Metals, Vol. 2, J.A. Szpunar, Ed., (National Research Council of Canada, 1999) pp.1106-1111.
11. "X-ray microbeam diffraction mapping of different texture scales important in fatigue cracking or in large deformations," S.R. Stock and Z. U. Rek, in Multiscale Phenomena in Materials--Experiments and Modeling, Materials Research Society Proceedings **578** (2000) 303-308.
12. "Nondestructive determination of the depth of different texture components in polycrystalline samples," C.R. Patterson II, K.I. Ignatiev, A. Guvenilir, J.D. Haase, R. Morano, Z.U. Rek and S.R. Stock, in Applications of Synchrotron Radiation to Materials Science V, Materials Research Society Proceedings **590** (2000) 253-258.
13. "X-ray microtomography of fatigue crack closure as a function of applied load in Al-Li 2090 T8E41Samples," R. Morano, S.R. Stock, G.R. Davis and J.C. Elliott, in Nondestructive Methods for Materials Characterization, Materials Research Society Proceedings **591** (2000) 31-35.
14. "X-ray Microbeam Diffraction Comparison of Mesostructures in Plates of Three Aluminum Alloys," K. Ignatiev, S.R. Stock, Z.U. Rek, Advances in X-ray Analysis (2000) in press.

Invited presentations:

1. "Three-dimensional Microbeam Diffraction Tomography of Fatigue Crack Asperities in Al-Li 2090," S.R. Stock, ASM International Symposium on Heat Treating, Chicago, IL, October 13, 1998.
2. "X-ray Microtomography and X-ray Microdiffraction," Dept. of Materials Science and Engineering, Ohio State University, May 26, 1999.
3. "X-ray Microbeams and Three-dimensional Microtexture Mapping," 48th Annual Denver X-ray Conference, August 1999, Steamboat Springs, CO.
4. "Computed Tomography, " 2000 ASM/TMS Spring Symposium Material Characterization, April 25-26, 2000, Schenectady, NY.
5. "X-ray microbeam diffraction: Rapid multi-length-scale characterization spanning micrometers to millimeters," 19th European Crystallographic Meeting, August 2000, Nancy, France.
6. "X-ray Microtomography of Engineering Structural Materials," Waterways Experimental Station, US Army Corps of Engineers, Vicksburg, MS, Dec. 2000.

Theses:

1. J.D. Haase, 1998, "Microbeam Diffraction Mapping of Microtexture in Al-Li 2090 T8E41."
2. R. Morano, 1998, "Effect of R-ratio on Crack Closure in Al-Li 2090 T8E41, Investigated Non-destructively with X-ray Micro-Tomography."
3. C.R. Patterson, II, 1999, "Synchrotron Polychromatic X-ray Diffraction Tomography of Aluminum Lithium 2090 T8E41."

E18-T23

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14. ABSTRACT

Micro- and meso-textures' roles in defining fatigue crack path in Al-Li 2090 T8E41 compact tension samples was the central focus of the research. Near-single crystal volumes up to 0.4 mm x 1 mm x 2 mm, i.e., stacks of five or more adjacent, pancake-shaped grains, comprise over 40 vol% of the center portions of 2090 plates; two other Al alloys showed little to no near-single crystal volumes. The synchrotron microbeam diffraction techniques (polychromatic x-radiation) developed in this research were also found to be useful in heavily-deformed copper and in Ti-6Al-4V samples.

15. SUBJECT TERMS
aluminum, texture, fatigue cracks, closure, synchrotron x-radiation, diffraction, microbeams.

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